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THE EFFECTS OF BANDWIDTH COMPRESSION ON IMAGE INTERPRETER PERFORMANCE

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Conventional imagery differing in resolution (8-inch ground resolved distance [GRD], 16-inch GRD, and 24-inch GRD), digitized and treated to represent four levels of bandwidth compression (1:1=no compression, 4:1, 8:1, and 10:1) was interpreted by 12 experienced image interpreters. A Greco-Latin square design was used to control for differences between interpreters, imagery subsets, and period effects at each GRD and to test the effects of bandwidth compression. The dichotomized image variables of sun angle, image contrast, and → over

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target obscurity were distributed equally across all conditions, but could be analyzed only for the 24-inch GRD imagery. Significant decreases were found in the number of correct identifications due to bandwidth compression; the largest decrease occurred between 4:1 and 8:1 bandwidth compression ratios. System developers should make careful trade-off evaluations in using bandwidth compression. More research in this area is required on the search function of interpretation and interactions of image variables.

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Sensor Systems
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FOREWORD

The Human Factors Technical Area of the Army Research Institute for the Behavioral and Social Sciences (ARI) is concerned with the human resource demands of increasingly complex battlefield systems for acquiring, transmitting, processing, and disseminating information. This increased complexity places greater demands on the operator using the machine system. Research in this area focuses on human performance problems related to interactions within command and control centers, as well as issues of system development. The research is concerned with such areas as software development, topographic products and procedures, tactical symbology, user-oriented systems, information management, staff operations and procedures, decision support, and sensor-system integration and use.

An area of special concern is the transmission of continuous-tone imagery in digital form to ground terminals in near-real-time. This is a prime requirement of intelligence and command-and-control systems, since much of the information contained in such imagery is extremely perishable. A key problem of such systems is the bandwidth requirement, for which one possible solution is the use of bandwidth compression techniques. This report describes research that partially determines the information loss in the interpretation of the imagery associated with degrees of bandwidth compression in image transmission. This research was a cooperative project among a number of agencies including ARI, the U.S. Army Space Projects Office, RCA, Inc., of Camden, N.J., and the U.S. Army Electronics R&D Command.

Research on sensor systems integration and utilization is conducted as an in-house effort augmented through contracts with organizations selected for their unique capabilities and facilities for research on sensor systems. The present in-house research was conducted in response to general requirements of Army Project 2Q763743A774 and to special requirements of the U.S. Army Space Projects Office, Washington, D.C. Special requirements are contained in Human Resources Need 77-271 (Human Factors Research and Evaluation of Advanced Imaging Systems).

Joseph Zeidner

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THE EFFECTS OF BANDWIDTH COMPRESSION ON IMAGE INTERPRETER PERFORMANCE

BRIEF

Requirement:

To determine the effect of bandwidth compression on the interpretability of digitized imagery.

Procedure:

Twelve experienced image interpreters were given about 3 hours of practice/training on digitized imagery containing all the different conditions in the experiment. Each participant then interpreted all the imagery in each of three "resolution sets"; first, 8-inch ground-resolved distance (GRD), vertical imagery; second, 16-inch GRD, vertical imagery; and third, 24-inch GRD, oblique imagery. Each set was divided into four subsets of images, each of which could be viewed at one of the four levels of bandwidth compression--1:1 (no compression), 4:1; 8:1; and 10:1.

To test the effects of bandwidth compression, a Greco-Latin square design was used to control for differences between interpreters, imagery subsets, and periods at each GRD. In the 24-inch GRD (oblique imagery) target difficulty was controlled to allow testing the effects of sun angle, image contrast, target obscurity, bandwidth compression, and their interactions on interpreter performance. At the other two GRDs, the first three variables were distributed equally across bandwidth compression, but could not be analyzed because of confounding with target differences in the imagery. The number of correct identifications and number of misidentifications were analyzed for each of five reporting levels of increasing detail of target identification--from simple detection (i.e., was a target present?) to the model number of target (e.g., self-propelled gun, M107).

Findings:

In general, the number of right responses decreased significantly as bandwidth compression increased for each resolution set (8-inch, 16-inch, and 24-inch GRD), but not for each level of detail of target identification. The largest decrease in right responses was from the second compression level (4:1) to the third compression level (8:1). Wrong identifications also tended to decrease as bandwidth compression increased.

Significant differences were found for target obscurity (only a few hidden targets were found) and for sun angle (high sun angle was better). Some interactions were found between bandwidth compression and sun angle and target obscurity. For example, under the low-sun-angle condition, the largest decrease in the number of right identifications due to bandwidth compression occurred at 4:1 compression level, whereas in the high-sun-angle condition, the largest decrease occurred between 4:1 and 8:1 compression levels.

Utilization of Findings:

Bandwidth compression of digitized imagery degrades interpreter performance. Users should carefully consider the trade-offs between different amounts of bandwidth compression and the degradation of interpreter performance. Developers of systems using bandwidth compression should collect more data concerning its effect on search performance of trained interpreters using large format imagery if more exact trade-off analyses are required.

Users and developers of such systems also should collect more data on the impact of the operational conditions (such as sun angle) to determine when bandwidth compression will be most effective and when it should not be used.

THE EFFECTS OF BANDWIDTH COMPRESSION ON IMAGE INTERPRETER PERFORMANCE

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THE EFFECTS OF BANDWIDTH COMPRESSION ON IMAGE INTERPRETER PERFORMANCE

INTRODUCTION

The transmission of continuous-tone imagery in digital form is of great interest to the Department of Defense for several specific applications. One such application is the near-real-time transmission of surveillance imagery to ground terminals. This is a prime requirement of intelligence and command-and-control systems, since much of the military information contained in such imagery is extremely perishable. One difficulty associated with the real-time transmission of imagery is the direct relation between image resolution and the bandwidth used for transmission. However, large bandwidth requirements are a serious problem for many reasons--for example, the bandwidth requirements of other systems, antenna size, interference with other systems, time for transmission, and jamming considerations. Unfortunately, reduced bandwidth and image degradation (and other problems) are inseparably linked in the real-time transmission of imagery.

A possible solution to this problem is the use of bandwidth compression. In this method, the digitized image is transformed to the frequency domain where many of the higher frequencies--possessing little image energy--are discarded. Theoretically, a minimum amount of image information is lost, and bandwidth requirements are reduced.

OBJECTIVE

The research objective was to determine the information loss associated with different degrees of bandwidth compression in image transmission. More specifically, this research investigated the effect of levels of bandwidth compression of digitized imagery on the number of right and wrong target identifications made by image interpreters for variations in operational conditions such as vertical and oblique imagery, image resolution, sun angle, image contrast, and target obscurity.

METHOD

Sample

Twelve experienced image interpreters of the U.S. Army Image Interpretation Center, Washington, D.C., participated in the experiment. The interpreters varied widely in age, experience, and rank, but the sample distribution could not be controlled to represent a particular population of image interpreters.

Procedure

The 12 image interpreters were first given an introduction describing the background of the experiment (Appendix A) and instructions on use of the Vehicle Target List, U.S. Equipment Mini-key, and the Report Form (Appendix B). To insure that the interpreters understood the instructions and to provide practice in interpreting digital imagery of scenes portraying American equipment processed with bandwidth compression, they next interpreted 10 vertical images containing two to three targets per image. This first set represented imagery with a ground-resolved distance (GRD) of 8 inches prior to compression and processing. After interpreting 6 to 10 targets at one compression level, they scored themselves, checked their interpretations, and proceeded to a different compression level until they completed practice at all four compression levels and on targets from all four major target categories. This procedure was repeated with 10 more vertical images with a 16-inch GRD before compression and processing. Interpreters then received 10 oblique images (optical axis 60 degrees from the horizontal) with a 24-inch GRD before compression and processing, and the same procedure was repeated. In this manner, the interpreters received practice on all procedures necessary for data-collection, on the use of the mini-key, on all target types employed, on all ground resolutions, and on all levels of bandwidth compression.

On the second day the interpreters received a short description of test procedures and imagery (Appendix C) and began interpreting the imagery. They worked for about 50 minutes on each set of imagery (8-inch, 16-inch, and 24-inch GRD), with a 10-minute break between sets.

Variables

Dependent Variables. Two primary dependent variables were used--number of right identifications and number of wrong identifications. The wrong score was composed mainly of misidentifications (i.e., giving the wrong name to a vehicle), but included some inventive errors (i.e., identifying a nonmilitary object as a military vehicle). Both scores were derived at five levels of reporting detail ranging from detection (Level I: military object versus nonmilitary object) to detailed interpretation (Level V: model number of object). Appendix B provides a detailed description of the five levels.

The image interpreters reported targets at the most detailed level they thought appropriate and were scored not only for this reporting level, but for all less-detailed reporting levels. Thus, an interpreter could report an object at Reporting Level V and be scored wrong at this level, also be scored wrong at Level IV, but be scored right at levels III, II, and I.

Independent Variables. Seven independent variables were employed:

1. Bandwidth compression level. Four levels of compression were used: 8+ bits/pel (pel = picture element)--this level had zero bandwidth compression; 2 bits/pel--4:1 bandwidth compression; 1 bit/pel--8:1 bandwidth compression; and .8 bit/pel--10:1 bandwidth compression.

2. Groups of interpreters. Four groups of three interpreters each were established. Groups were matched subjectively for ability by their supervisors.

3. Periods. Four work periods (first, second, third, and fourth) were used to control for time-related effects such as practice and fatigue.

4. Scenario. Four scenarios were used; each scenario consisted of an image matrix of 10 image chips (8 chips scorable).

5. Target obscurity. In the third experiment, with 24-inch GRD imagery, half the targets imaged were in the open and the other half were visible but embedded in vegetation.[1]

6. Sun angle. In the third experiment, half the imagery was taken with a sun angle of 62 degrees from the horizontal, and the other half of the imagery was taken with a sun angle of 18 degrees from the horizontal.[1]

7. Contrast. In the third experiment, half the imagery was processed to produce a high-contrast image (i.e., with dense black shadow), and the other half was processed to produce low-contrast images (i.e., with light but visible shadows). No physical measurements of the resulting contrast levels were made.[1]

Design

To simplify the research design, each of the three ground resolutions was considered as separate experiment: I, 8-inch GRD; II, 16-inch GRD; and III, 24-inch GRD. An identical Greco-Latin square was used in each experiment to counterbalance the independent variables--groups, scenarios, periods, and bandwidth compression levels (Table 1). A 2 x 2 x 2 arrangement of the image variables--sun angle, contrast, and target obscurity--was present in each scenario, as shown in Table 2. Since each image contained different targets, image variables became confounded with target

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[1] In experiment 3, the imagery was obtained in the laboratory using models wherein target difficulty and image variables could be controlled. In experiments 1 and 2, the imagery was selected from a library of U.S. Army maneuver photography; the judgment of interpreters and "take" conditions were used to define the target difficulty and image variables.

type and were not analyzed for the 8-inch and 16-inch imagery. However, for the 24-inch ground resolution imagery, sufficient control of target type was possible to roughly equalize estimated target difficulty across these variables; hence, an analysis could be performed for 24-inch GRD imagery without serious confounding (see Table 3). A 2 x 2 x 2 x 4 factorial analysis of variance design was used to investigate the variables--sun angle, contrast, target obscurity, bandwidth compression level--and their interactions.

Table 1

Greco-Latin Square Design

Group	Period 1	Period 2	Period 3	Period 4
G_1	T_4/S_1	T_1/S_4	T_3/S_3	T_2/S_2
G_2	T_1/S_3	T_4/S_2	T_2/S_1	T_3/S_4
G_3	T_2/S_4	T_3/S_1	T_1/S_2	T_4/S_3
G_4	T_3/S_2	T_2/S_3	T_4/S_4	T_1/S_1

Note: T = bandwidth compression level; S = scenario.

Theoretically, each of the above analyses could have been carried out for each of the five reporting levels and for each of the dependent variables (right identification and wrong identifications). In some cases, however, insufficient data were available for analysis, e.g., right identifications at the level of greatest target detail (Reporting Level V).

Stimulus Materials

Four sets of scenarios for each experiment were constructed to meet experimental design considerations while simulating operational conditions. Each scenario consisted of an image mosaic of 10 image chips (positive transparencies). Eight of these image chips contained from one to six targets and were used to obtain the experimental data. The other two chips contained no targets and were included to reduce the attractiveness of guessing; any reports made for these chips were not used in the analyses.

Table 2

Variables Within Each Scenario

Scenario	High sun angle				Low sun angle			
	High contrast		Low contrast		High contrast		Low contrast	
	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured
S_1	58[a]	57	54	45	68	67	64	63
S_2	66	65	70	69	52	43	48	71
S_3	42	49	62	53	44	59	56	47
S_4	50	41	46	61	60	51	72	55

[a]Photo number.

Table 3

Distribution of Targets, 24-Inch GRD,
Target Size Versus Sun Angle x Contrast x Target Obscurity

Target size	High sun angle				Low sun angle				Total
	High contrast		Low contrast		High contrast		Low contrast		
	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured	
Large	2	5	2	4	3	2	5	2	25
Medium	2	2	3	3	3	3	2	3	21
Small	4	1	3	1	2	3	1	3	18
Total	8	8	8	8	8	8	8	8	64

The chips were arranged in the image mosaic as shown in Appendix D (Figure D-1). The lower position of the mosaic contained a rectangular array of numbers. The numbers in the top row were mosaic identification numbers, and the numbers in the lower four rows were the image identification numbers corresponding to the 10 image chips.

Each of the eight chips containing targets represented one combination of the bilevel independent variables--sun angle, contrast, and target obscurity. An attempt was made to insure that at least two chips contained one target each from the four major target categories (tracked vehicles--armor, wheeled vehicles, engineer equipment; and miscellaneous--trailers, towed artillery, or aircraft). Thus, each scenario represented a wide variety of operational conditions.

Actually, only the 24-inch resolution scenarios (Table 3) met these specifications sufficiently for analysis purposes. These scenarios were photographed using detailed target models displayed on a realistic terrain board of 1:80 scale, to obtain the desired distribution of conditions. The 8-inch and 16-inch GRD scenarios (vertical photography) used imagery photographed over the Camp Drum Military Reservation in upper New York State. This imagery contained few target objects of engineer equipment or of the miscellaneous category, but it did satisfy most of the other design requirements.

A few gaps in the desired design of scenarios occurred because of the lack of suitable imagery or because of problems concerning image digitization. Appendix D gives the image matrix and tragets contained in each image. A complete discussion of the details of the digitization and bandwidth compression (two-dimensional cosine transform) of the is given in Butler, et al., 1975.[2]

RESULTS

The Greco-Latin square design controlled for differences among interpreters, scenarios, and periods in testing the effects of bandwidth compression on interpreter performance. Data are presented in this section only for the bandwidth compression variable. The data and results for each experiment for the control variables--groups, scenarios, and periods--appear in Appendix E.

For each situation where the bandwidth compression variable produced a significant change in interpreter performance, the differences in mean performance between the four levels were tested using the Newman-Keuls Test. (See Appendix F for detailed results.)

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[2]Butler, J., DiRusso, E., Martinson, L., Rudnick, J., and Wild, G. (U) Digital Data Transmission System Study (SECRET). RCA Government Communications Systems Division, Contract DACA 76-75-C-0003, for U.S. Army Engineer Topographic Laboratories, 17 December 1975.

The results of the analyses of variance for the three parallel experiments (8-inch GRD, 16-inch GRD, and 24-inch GRD) are reported separately--first for the right identifications for each reporting level and then for the wrong identifications for each reporting level. Next, additional analyses concerning the image variables and bandwidth compression are given for the 24-inch GRD imagery. Finally, the results are summarized across the three experiments.

Eight-Inch Ground Resolution

Right Identification Scores. Table 4 shows the results of the analyses of variance for the number of right identifications for the independent variables versus four reporting levels. (Reporting Level V was omitted because of insufficient data.) Bandwidth compression level and scenario (discussed in Appendix E) were associated with significant differences at one or more reporting levels.

At Reporting Level I, there was no significant deterioration in performance. At this level, the interpreter is making a target/nontarget judgment for each spot on the image that attracts his attention. This decision appears to be made with about the same level of proficiency at all bandwidth levels.

Table 4

Analysis of Variance Summary for Right Identifications, Independent Variables Versus Reporting Level (8-inch GRD)

Independent variable	Reporting level I	II	III	IV	V[a]
Groups					-
Periods					-
Bandwidth compression level		**			-
Scenario	**	**	**	**	-
Residual					-

**Significant at the .01 level.

[a]Insufficient data.

At Reporting Level II, compression produced a significant effect. At this level, the number of right identifications is higher for the 8+ bits/pel level than for the other three bandwidth levels (see Table 5). At Reporting Level II, the interpreter must identify the class of vehicle--tracked, wheeled, trailer-artillery-aircraft, or engineer equipment. The task of identifying the cues and signatures necessary for successfully distinguishing among the four target categories was significantly affected by bandwidth compression.

The data on Reporting Levels III, IV, and V indicated that these more detailed interpretations were very difficult to make at any level of bandwidth compression. There was a 50% reduction in the number of right identifications for each reporting level. However, there were no significant differences in performance due to bandwidth compression.

Table 5

Number of Right Identifications, Bandwidth Compression Level Versus Reporting Level (8-inch GRD)

Bandwidth compression level	Reporting level				
	I	II	III	IV	V[a]
8+ bits/pel	108	96	48	22	6
2 bits/pel	100	74	37	16	8
1 bit/pel	86	60	39	20	9
0.8 bit/pel	93	78	37	20	7

[a]Insufficient data--not analyzed.

For the relatively simple task of detection (Reporting Level I) with the best quality imagery (8+ bits/pel), the interpreters made 108 correct detections out of the 165 possible; that is, they detected about 63% of the available targets. This very low performance resulted from the conditions of the experiment--not the quality of the interpreters. Interpreters typically are not trained or experienced in the recognition factors of American equipment portrayed in the images, nor on digitized imagery of any kind. Additionally, the experimental procedures, equipment, and unusual conditions also could have reduced the level of performance. Since the experimental imagery did not include continuous-tone imagery as a control, the effect of digitizing along could not be assessed. Thus, although the relative effects of bandwidth compression and other factors can be determined, the operational level of performance anticipated cannot be assessed.

In summary, bandwidth compression apparently did not affect detection but did affect the first level of identification. Other levels of identifications apparently were not significantly affected.

Wrong Identification Scores. Table 6 gives the result of the analyses of variance for independent variables versus the five reporting levels. The three significant variables are groups, bandwidth compression, and scenarios. Group and scenario effects are given in Appendix E.

Table 6

Analysis of Variance Summary for Wrong Identifications, Independent Variables Versus Reporting Level (8-inch GRD)

Independent variables	Reporting level I[a]	II	III	IV	V
Groups	-				*
Periods	-				
Compression levels	-		*		
Scenarios	-	**	**	*	**
Residual	-				

*Significant at the .05 level.
**Significant at the .01 level.

[a]Insufficient data.

Bandwidth compression levels differed significantly for Reporting Level III for the number of wrong identifications made. Table 7 presents the number of wrong identifications by bandwidth compression level and reporting level. At a compression ratio of 8:1 (1 bit/pel), the number of wrong identifications is much lower than for any of the other three compression levels. The reason for this is not known. Compounding the confusion, performance is poorest at both 8 bits/pel and .8 bit/pel.

Table 7

Number of Wrong Identifications, Bandwidth Compression Level Versus Reporting Level (8-inch GRD)

Bandwidth compression level	Reporting level				
	I[a]	II	III	IV	V
8+ bits/pel	-	10	34	38	40
2 bits/pel	-	15	23	32	31
1 bit/pel	-	16	14	22	25
.8 bit/pel	-	11	31	31	31

[a]Insufficient data.

Sixteen-Inch Ground Resolution

Right Identification Scores. Table 8 gives the analysis of variance summary for the right identifications by independent variables versus reporting level. All the independent variables were associated with significant differences at one or more of the reporting levels. In addition, a significant residual was found for Reporting Level I, indicating that the assumption of no interactions among the independent variables is not verified. Thus, it is possible that two or more variables could have interacted to produce a significant effect in another one. Only the compression variable is discussed in this section; the other variables are described in Appendix E.

Significant differences (Table 8) in performance due to bandwidth compression were found at each reporting level. Table 9 gives the number of right identifications for bandwidth compression level versus reporting level. The greater the bandwidth compression, the poorer the performance, with but one (minor) inversion.

As with the 8-inch GRD results, there was a sharp drop in performance after Reporting Level II--even to the extent of precluding analysis at Reporting Level V. However, significant differences were found for the four compression levels tested, clearly indicating the detrimental effect of bandwidth compression on performance. The largest effect occurred at the 1 bit/pel compression level for Reporting Levels I, II, and III, and at the 2 bits/pel for Reporting Level IV.

Table 8

Analysis of Variance Summary for Right Identifications, Independent Variables Versus Reporting Level (16-inch GRD)

Independent variables	Reporting level I	II	III	IV	V[a]
Groups			**		-
Periods			*		-
Bandwidth compression level	**	**	**	*	-
Scenario	**	**	*		-
Residual	*				

*Significant at the .05 level.
**Significant at the .01 level.

[a]Insufficient data.

Table 9

Number of Right Identifications, Bandwidth Compression Level Versus Reporting Level (16-inch GRD)

Bandwidth compression level	Reporting level I	II	III	IV	V[a]
8+ bits/pel	93	67	31	17	-
2 bits/pel	89	61	20	7	-
1 bit/pel	66	37	7	3	-
.8 bit/pel	59	31	6	5	-

[a]Insufficient data.

Wrong Identification Scores. Table 10 presents the analysis of variance summary for independent variables versus reporting level. The only independent variable on which performance differed significantly

was bandwidth compression. Reporting Level V had a significant residual, indicating that there may have been interactions among the independent variables.

Table 10

Analysis of Variance Summary for Wrong Identifications, Independent Variables Versus Reporting Level (16-inch GRD)

Independent variable	Reporting level				
	I[a]	II	III	IV	V
Groups	-				
Periods	-				
Bandwidth compression level	-			*	*
Scenario	-				
Residual	-				*

*Significant at the .05 level.

[a]Insufficient data.

Table 11 shows the number of wrong identifications for bandwidth compression level by reporting level. The number of wrong identifications differed significantly among bandwidth compression levels for Reporting Levels IV and V. The number of wrong responses decreased with an increase in bandwidth compression level for these reporting levels.

In both experiments, there was a decrease in right identifications associated with bandwidth compression and also a decrease in wrong identifications. Bandwidth compression acted to decrease the overall output of interpreters (total number of identifications attempted). As the image became more degraded, the interpreter was less able to make the more precise identifications and did not attempt to do so.

Twenty-Four-Inch Ground Resolution

Right Identification Scores. Table 12 presents the analysis of variance summary for independent variables versus reporting level for the number of right identifications. Bandwidth compression level is the only

variable for which significant differences were obtained. Table 13 gives the number of correct identifications for bandwidth compression level by reporting level.

Table 11

Number of Wrong Identifications, Bandwidth Compression Level Versus Reporting Level (16-inch GRD)

Bandwidth compression level		Reporting level			
	I[a]	II	III	IV	V
8+ bits/pel	-	21	26	22	22
2 bits/pel	-	18	21	11	8
1 bit/pel	-	13	10	4	2
.8 bit/pel	-	18	16	7	6

[a]Insufficient data.

Table 12

Analysis of Variance Summary for Right Identifications, Independent Variables Versus Reporting Level (24-inch GRD)

Independent variables		Reporting level			
	I	II	III	IV	V[a]
Groups					-
Periods					-
Bandwidth compression level		**	**	**	-
Scenario					-
Residual					-

**Significant at the .01 level.

[a]Insufficient data.

Table 13

Number of Right Identifications, Bandwidth Compression Level Versus Reporting Level (24-inch GRD)

Bandwidth compression level		Reporting level				
		I	II	III	IV	V[a]
8+	bits/pel	72	48	18	9	-
2	bits/pel	67	41	16	6	-
1	bit/pel	54	17	3	1	-
.8	bit/pel	55	21	2	0	-

[a]Insufficient data.

At Reporting Level 1, detection, the number of right identifications declined with increasing bandwidth compression, although no statistically significant differences were found. For Reporting Levels II, III, and IV, there was a statistically significant decrease in correct identifications as bandwidth compression level increased. As in the previous experiments, the largest decrease occurred between compression levels 4:1 and 8:1.

Wrong Identification Scores. None of the independent variables was associated with a significant outcome at any reporting level; therefore, no analysis of variance summary is given.

For comparison with other results, Table 14 presents the number of wrong identifications for bandwidth compression level versus reporting level. These data will be used in a subsequent discussion and are reported here simply for convenience.

Effect of Image Variables on Interpreter Performances. As described earlier, the 24-inch ground resolution experiment provided sufficient control of target type and size to permit a rough equalization of target difficulty across bandwidth compression level, sun angle, contrast, and target obscurity, making possible a 2 x 2 x 2 x 4 analysis of variance design. The low number of wrong responses precluded their analysis. The number of right identifications were analyzed at Reporting Levels I, II, and III only. The number of responses for the other two levels were insufficient to justify a breakout for the 2 x 2 x 2 x 4 analysis. The results of the analysis are discussed separately by reporting level and then combined. Since the 24-inch ground resolution imagery was oblique photography, generalization of results to vertical imagery should be done with caution.

Table 14

Number of Wrong Identifications, Bandwidth Compression Level Versus Reporting Level (24-inch GRD)

Bandwidth compression level		Reporting level				
		I[a]	II	III	IV	V[a]
8+	bits/pel	-	17	18	9	-
2	bits/pel	-	23	15	6	-
1	bit/pel	-	22	17	5	-
.8	bit/pel	-	20	11	4	-

[a]Insufficient data.

Reporting Level I. Table 15 shows that target obscurity, sun angle, and the three-way interaction among target obscurity-contrast-sun angle significantly affected interpreter performance. Table 16 shows the frequency of correct responses presented by bandwidth compression level versus target obscurity-contrast-sun angle. This table details the two main effects and one triple interaction that were statistically significant. For example, the number of obscured targets detected can be determined by adding the four left-hand column totals to give the sum of 45 correct detections for obscured targets. The total of unobscured targets detected is the sum of the four right-hand column totals, or 205 target detections. Subjects detected more than 4.5 times as many unobscured targets as targets obscured by vegetation. Clearly, a blob in the open was much easier to recognize as a target than the same blob surrounded by similar blobs of vegetation.

Sun angle significantly affected interpreter performance. The sum totals of all columns labeled high sun angle in Table 23 yield 141 targets detected. Similarly, summing the totals of those columns labeled low sun angle gives a total of 109 targets. When the length of shadow was short, as in the case of the high sun angle, the number of correct detections increased.

The triple interaction among target obscurity-contrast-sun angle significantly influenced interpreter performance. Table 17 shows the frequencies of correct responses when target obscurity is tabulated against contrast and sun angle. These data show that, for high-contrast imagery, the number of correct detections for high sun angle was greater than for low sun angle for both the obscured and unobscured targets. For the low-contrast imagery, the high sun angle resulted in the detection of more obscured targets than the low sun angle, but had little or no effect

on the detection of unobscured targets. This fact should be of use to mission planners in deciding when to fly surveillance missions. Translated into operational terms: if the day is bright and shadows are sharp and distinct, a mission should be flown when the sun is high; however, if a mission is required when the day is overcast and shadows are weak or nonexistent, the mission can be flown at any time of day (given sufficient light), although a few obscured targets may be missed.

Table 15

Analysis of Variance Summary for Right Identifications, Bandwidth Compression Level and Image Variables Versus Reporting Level (24-inch GRD)

Variables	Reporting level I	Reporting level II	Reporting level III	Remarks
A Bandwidth compression level		**	**	Similar to previous results.
B Obscured/unobscured	**	**	**	Few responses for obscured targets.
C High/low contrast				
D High/low sun angle	**	**	**	High sun angle better.
AB		**	**	See B above.
AC				
AD			*	Low sun angle--gradual decrease due to bandwidth compression. High sun angle--abrupt change.
BC				
BD		**	**	Few responses for obscured targets.
CD				
ABC				
ABD			*	See AD and B.
ACD				
BCD	*			See B above. High contrast shows drop in low sun angle; low contrast shows no difference.
ABCD				

*Significant at the .05 level.
**Significant at the .01 level.

Table 16

Reporting Level I: Number of Correct Detections-Bandwidth Compression Level Versus Sun Angle x Contrast x Target Obscurity (24-inch GRD)

Bandwidth compression level	Obscured				Unobscured				Total
	High contrast		Low contrast		High contrast		Low contrast		
	High sun angle	Low sun angle	High sun angle	Low sun angle	High sun angle	Low sun angle	High sun angle	Low sun angle	
8+ bits/pel	5	1	4	2	18	13	16	14	73
2 bits/pel	5	2	2	2	17	10	16	13	67
1 bit/pel	2	4	4	1	12	8	10	13	54
8 bit/pel	2	3	4	2	15	8	9	13	56
Total	14	10	14	7	62	39	51	53	250

Table 17

Reporting Level I: Number of Correct Detections, Target Obscurity Versus Sun Angle x Contrast (24-inch GRD)

Target obscurity	High contrast		Low contrast	
	High sun angle	Low sun angle	High sun angle	Low sun angle
Obscured	14	10	14	7
Unobscured	62	39	51	53

Reporting Level II. Table 15 shows three significant main effects for Reporting Level II--compression level, target obscurity, and sun angle--and two significant two-way interactions--one between bandwidth compression level and target obscurity and another between target obscurity and sun angle. Table 18 shows the number of correct identifications by bandwidth compression level versus target obscurity and sun angle.

Table 18

Reporting Level II, Number of Correct Identifications, Bandwidth Compression Level Versus Sun Angle x Target Obscurity (24-inch GRD)

Bandwidth compression level	Obscured		Unobscured		Total
	High sun angle	Low sun angle	High sun angle	Low sun angle	
8+ bits/pel	4	0	28	16	48
2 bits/pel	3	3	25	10	41
1 bit/pel	0	0	11	6	17
.8 bit/pel	1	0	13	7	21
Total	8	3	77	39	127

Bandwidth compression level produced a significant effect on interpreter performance. For the no-compression condition (8+ bits/pel) and for the 4:1 compression condition, the number of correct responses was relatively high (see Table 18). For the 8:1 and 10:1 compression conditions, performance dropped severely. This result is similar to that observed in the previous analyses.

Target obscurity significantly altered performance. Table 18 shows that only 11 obscured targets were identified correctly, whereas 116 unobscured targets were identified correctly. The distraction introduced by vegetation reduced the number of correct identifications by a factor of 10.

The sun angle during the mission also significantly altered interpreter performance. If the imagery was taken when the sun angle was high, 85 targets were correctly identified; with a low-sun-angle condition, only 42 targets were correctly identified. A possible reason for this effect is that target details were hidden by the more extensive shadows produced by the low sun angle.

The most striking thing about Table 18 is the number of zero entries in the two left-hand columns. Only 11 correct identifications were made of obscured targets. The extremely small number of responses makes any interpretation of the interactions involving obscured targets questionable.

Bandwidth compression level interacted with target obscurity to produce a significant change in interpreter performance (Table 19). However, because there were so few correct responses for the obscured target condition, this effect must be interpreted cautiously. Apparently, increased bandwidth after 2 bits/pel had a greater detrimental effect on obscured targets than on unobscured targets.

Table 19

Reporting Level II: Number of Correct Identifications, Target Obscurity Versus Bandwidth Compression Level (24-inch GRD)

Target obscurity	Bandwidth compression level			
	8+ bits/pel	2 bits/pel	1 bit/pel	.8 bit/pel
Obscured	4	6	0	1
Unobscured	44	35	17	20
Total	48	41	17	21

Although the target obscurity by sun-angle interaction was significant, again the interaction should be generalized cautiously because of the small number of correct responses for the obscured targets. A total of 11 targets were reported under the obscured condition, 8 for the high-sun-angle condition and 3 for the low-sun-angle condition. Under the unobscured condition, the frequencies are 77 and 39. A greater, detrimental effect of low sun angle occurred for obscured targets.

Reporting Level III. At this reporting level, the interpreter identified the type of target detected (e.g., tank, cargo truck, trailer, self-propelled gun). This required the ability to identify additional cues and signatures of the target that permit more detailed identification. Table 15 shows that for Reporting Level III, there were three significant main effects--bandwidth compression level, target obscurity, and sun angle--and four significant interactions--bandwidth compression level by target obscurity, bandwidth compression level by sun angle, target obscurity by sun angle, and bandwidth compression level by target obscurity by sun angle.

Table 20 shows the frequency of correct identifications presented by bandwidth compression level versus sun angle-contrast-target obscurity. The large number of zero entries in Table 20 is, again, striking. Discounting marginal totals, of the 32 cells in Table 20, 21 cells are zero. With such a large number of zeros, the analysis of these data may be unstable, and all of the interactions cannot be validly generalized.

Bandwidth compression level was statistically significant. The right-hand column of Table 20 shows the frequency of correct identifications by bandwidth level. This result is consistent with previous findings of this research and shows that there is a sharp decline in performance between 2 bits/pel and 1 bit/pel.

Target obscurity had a significant effect: there were 37 correct responses for unobscured targets, but only 2 correct responses for obscured targets. The interpreters had great difficulty in making correct identifications with the 24-inch GRD imagery when the targets were embedded in vegetation.

Sun angle produced a significant difference in performance. With a high sun angle, there were 31 correct responses; at a low sun angle, there were only 8 correct identifications. This result is consistent with the results at other reporting levels.

Table 21 presents the significant triple interaction and shows the number of correct identification in each of the 16 possible categories. Since only two obscured targets were correctly identified, this significant triple interaction probably occurred because one cell contained two responses; i.e., there are too few observations to make a reasonable interpretation.

Table 21 also can be used to examine the three two-way interactions as well as the triple interaction. For the interaction between bandwidth compression level and target obscurity, the values for each bandwidth level can be determined by adding the entries for high and low sun angles under the obscured target heading and doing the same for the entries under the unobscured target heading. The number of correct identifications at a bandwidth of 8+ bits/pel is two for obscured targets and zero at all other bandwidth levels. For unobscured targets, the number of correct identifications at a bandwidth of 8+ bits/pel level is 16; the numbers are 16, 3, and 2, respectively, at the other three bandwidths. It could be argued that the drop off in performance associated with bandwidth compression occurred sooner with unobscured targets than with obscured targets. Such an argument is questionable, because, again, too few obscured targets were identified to give credibility to such an interpretation.

Table 20

Reporting Level III: Number of Correct Identifications, Bandwidth Compression Level Versus Sun Angle x Contrast x Target Obscurity (24-inch GRD)

Bandwidth compression level	Obscured				Unobscured				Total
	High contrast		Low contrast		High contrast		Low contrast		
	High sun angle	Low sun angle	High sun angle	Low sun angle	High sun angle	Low sun angle	High sun angle	Low sun angle	
8+ bits/pel	2	0	0	0	5	1	6	4	18
2 bits/pel	0	0	0	0	9	0	5	2	16
1 bit/pel	0	0	0	0	0	0	2	1	3
.8 bit/pel	0	0	0	0	0	0	2	0	2
Total	2	0	0	0	14	1	15	7	39

Table 21

Reporting Level III: Number of Correct Identifications, Bandwidth Compression Level Versus Sun Angle x Target Obscurity (24-inch GRD)

Bandwidth compression level	Obscured		Unobscured		
	High sun angle	Low sun angle	High sun angle	Low sun angle	Total
8+ bits/pel	2	0	11	5	18
2 bits/pel	0	0	14	2	16
1 bit/pel	0	0	2	1	3
.8 bit/pel	0	0	2	0	2
Total	2	0	29	8	39

The bandwidth compression level by sun-angle interaction can be examined (Table 21) in a manner similar to that above. If the results for the obscured targets were added to those for the unobscured, the only change that would occur from the results with unobscured targets is that the number of correct detections at 8+ bits/pel is 13 instead of 11. It appears that with a low sun angle, the use of bandwidth compression quickly reduces the number of correct identifications, but that some bandwidth compression can be tolerated with a high sun angle.

The final two-way interaction is the target obscurity by sun angle interaction. Here again, there are too few responses to make any reasonable interpretation.

Summary Across Reporting Levels

Combining these results across reporting levels leads to the following conclusions:

Bandwidth Compression. The number of correct target identification is significantly reduced by bandwidth compression; the largest decrease occurred at a compression ratio of 8:1 (1 bit/pel).

Sun Angle. Detection and identification of targets is facilitated by a high sun angle. Sun angle interacted with bandwidth compression to reduce the number of correct identifications under low sun angle, but had little effect at low compression (4:1) under high sun angle. Although high sun angle is generally better, sun angle does not affect detection of targets (Reporting Level I) under low-contrast conditions for unobscured targets.

Target Obscurity. In the digitized imagery used in this experiment, military targets surrounded by vegetation are extremely difficult to detect and identify.

Other Interactions. Inspection of these interactions revealed that most involved target obscurity for which there were few responses at one or both levels of the variable. With so few values, interpretation of these interactions was considered tenuous.

Summary Across GRD Levels

The results at each of the three ground resolutions are summarized across the three parallel experiments, first in terms of right identifications, and then in terms of wrong identifications.

Right Identifications. The number of correct identifications is summarized in Table 22 in terms of bandwidth compression ratio at each GRD for each of the five levels of reporting. The 8-inch and 16-inch GRD images were vertical photographs, and the 24-inch GRD images were oblique photographs. However, the effect on interpreter performance produced by the vertical/oblique dichotomy cannot be determined in this research.

The data in Table 22 are plotted in Figure 1, providing a set of three curves for each reporting level--a separate curve for the 8-inch, 16-inch, and 24-inch GRDs. (No plot for Reporting Level V was made, since data were available only for the 8-inch GRD.

In Figure 1, the bandwidth compression factor is plotted along a logarithmic scale, and information extracted--number of correct responses--is plotted along an equal division scale. The following is the rationale for plotting the results for the 16-inch and 24-inch GRD imagery beginning at 4:1 and 9:1 respectively, on the same bandwidth reduction scale as for the 8-inch GRD imagery.

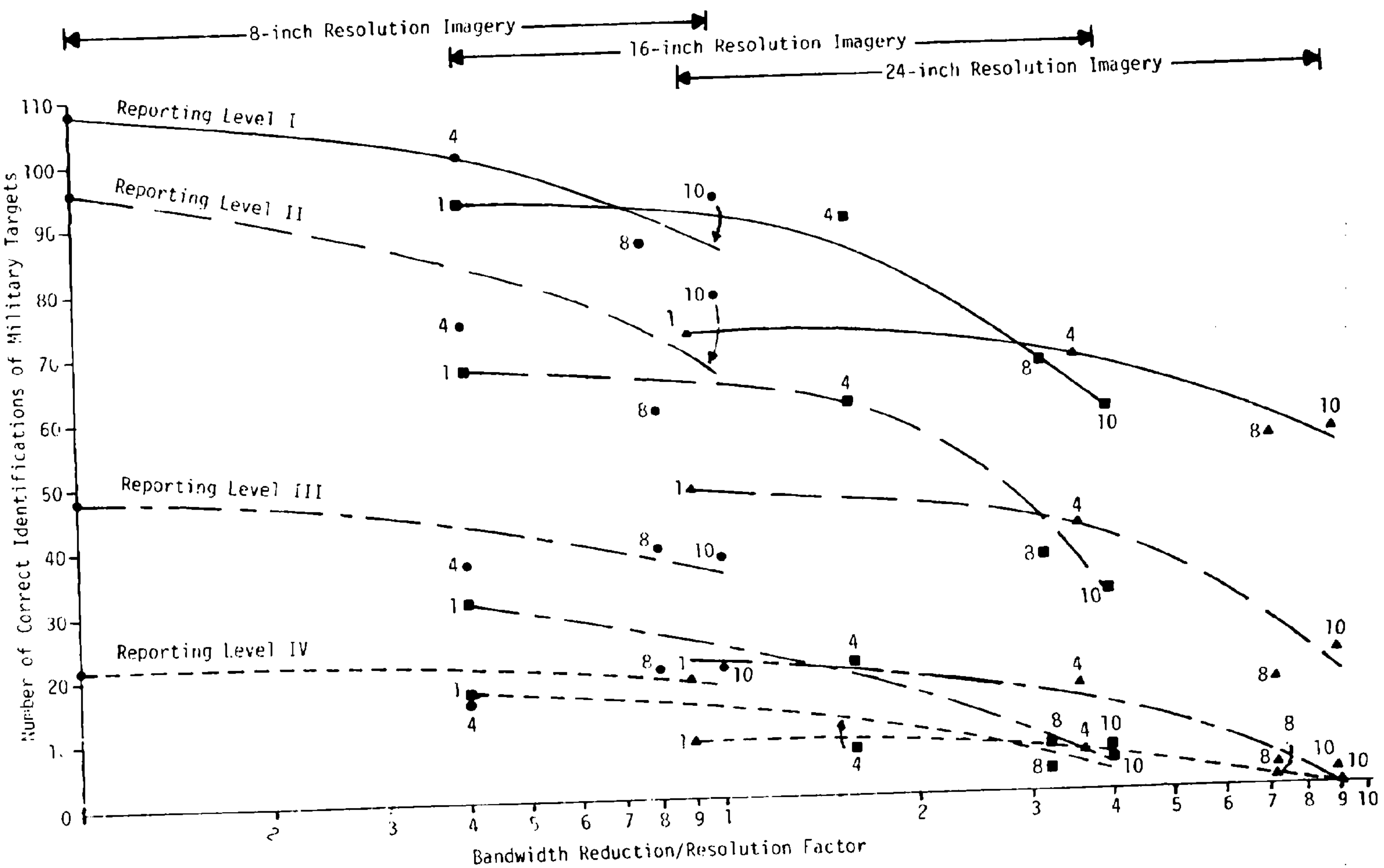
Analytically, there is a logarithmic relationship between bandwidth and the information content of the image. Degradation of imagery by increasing the size of the GRD can be assumed to have an effect analogous to that of bandwidth compression. If the original image has an 8-inch GRD and then is degraded photographically (by defocusing or other means) to a 16-inch GRD, the degraded image reflects a change of 2:1 along the width and length dimensions of the degraded image. In area, this is a 4:1 change. By a similar argument, the 24-inch GRD imagery represents a 3:1 linear change or a 9:1 area change over the 8-inch GRD image.

Table 22

Number of Right Identifications, Bandwidth Compression Level Versus Ground Resolution x Reporting Level

Bandwidth compression		Reporting level I			II			III			IV			V[a]		
		GRD inches														
Ratio	Level	8	16	24	8	16	24	8	16	24	8	16	24	8	16	24
1:1	8+ bits/pel	108	93	72	96	67	48	48	31	18	22	17	9	--	--	--
4:1	2 bits/pel	100	89	67	74	61	41	37	20	16	16	7	6	--	--	--
8:1	1 bit/pel	86	66	54	60	37	17	39	7	3	20	3	1	--	--	--
10:1	.8 bit/pel	93	59	55	78	31	21	37	6	2	20	5	0	--	--	--
Total		387	307	248	308	196	127	161	64	39	78	32	16	--	--	--

[a] Insufficient data.



NOTE: See text for assumptions limiting comparisons across imagery

Figure 1. Effect of bandwidth reduction/resolution on number of correct identifications for Reporting Levels I, II, III, and IV.

The set of three curves for Reporting Level I is in the upper part of Figure 1. For the 8-inch GRD curve, the 1:1 compression ratio shows that the interpreters detected 108 targets, or 65% of those in the imagery. At the 8:1 compression ratio, about 50% of the targets were detected. At the 8:1 compression ratio for the 24-inch GRD curve, only 27% of the possible targets were detected. The deterioration of interpreter detection performance is a joint effect of GRD and bandwidth compression.

The second set of three curves in the upper portion of Figure 1 is for Reporting Level II--identification of the target class (e.g., tracked vehicle). The 1:1 compression ratio for 8-inch GRD shows 96 correct identifications, or about 58%, and 17 correct identifications at the 8:1 compression ratio for the 24-inch GRD imagery, or about 9%.

The third set of curves in Figure 1 shows the number of correct responses for Reporting Level III. This level of reporting requires that the interpreter designate the type of military target in general terms (e.g., cargo truck). Performance at this level ranges from 48 correct at the 1:1 compression ratio for 8-inch GRD imagery to 2 correct at the 10:1 compression ratio for 24-inch GRD imagery. Thus, the performance range is from about 29% to 2% of the number of possible identifications.

The three curves at the bottom of Figure 1 are for Reporting Level IV--identification by target type (e.g., 2-1/2-ton truck). Here the range from highest to lowest performance is from 22 at the 1:1 compression ratio for 8-inch GRD to zero for the 10:1 compression ratio for the 24-inch GRD imagery. Target type identifications ranged from 13% to 0% of the number of possible identifications.

Based upon these results, it appears that the utility of bandwidth compression cannot be assessed without specifying the nature of the task to be performed. For Reporting Level I, if a level of 50% correct detection performance were considered acceptable, then for 8-inch GRD imagery all compression ratios would be satisfactory, as well as the 1:1 and 4:1 compression ratios for the 16-inch GRD imagery. For detailed interpretation like that required for Reporting Level IV, performances obtained in this research would be unsatisfactory at all levels of GRD and at all compression ratios.

In respect to the above performance figures, it should be noted that the image interpreters participating in these experiments had little or no previous experience with digitized imagery. The training/practice period used in this research was too brief to provide the experience level of an "operationally ready" interpreter. This lack of experience/training depressed performance below what would be expected if the interpreters had received a reasonable amount of training and experience in the interpretation of digitized imagery.

Wrong Identifications. Table 23 summarizes the number of wrong identifications in the same format as that used for the number of right identifications. These data are graphed in the same manner as the right identifications and appear as Figure 2 and Figure 3. Two figures are used to make the different curves distinct. Figure 2 shows the sets of curves for Reporting Levels II and IV. The alignment of the three curves in each set is not as distinct for the wrong identifications as it was for the right identifications. The separate curves for the three GRD levels in a set have been labeled to indicate the reporting level represented. The three curves in Figure 2 labeled Level II show that there were relatively few wrong identifications--for the 8-inch GRD (10 to 16), for the 16-inch GRD (13 to 21), and for the 24-inch GRD (17 to 23)--but the trend was for the number of wrong identifications to increase with a reduction of image quality. However, curves for Reporting Level IV (Figure 2) show a consistent decline in the number of wrong identifications with a reduction of image quality both by GRD and bandwidth compression--from a high of 37 misidentifications to a low of 4 misidentifications. Similarly, for Reporting Levels III and V, the number of wrong identifications drops steadily with image degradation (Figure 3).

Thus, it appears that in the more detailed interpretation associated with Reporting Levels III, IV, V, the interpreters were able to accurately judge the quality of imagery and reduce the frequency of their identifications as image quality was reduced, thereby reducing the number of wrong identifications (but unfortunately also reducing the number of right identifications).[3] However, for Reporting Level II (gross target class identification), the interpreters did not judge the quality of imagery as accurately, and consequently produced more wrong identifications as image quality decreased either by GRD, or bandwidth compression, or both.

CONCLUSIONS

1. Bandwidth compression of digitized imagery of various ground resolutions reduces the number of targets detected and identified (at several levels of detail) by image interpreters. Although there is some reduction in performance in the first level of compression (4:1), the largest decrease is between compression ratios of 4:1 to 8:1.

2. Generally, bandwidth compression reduces the number of wrong target identifications made by image interpreters.

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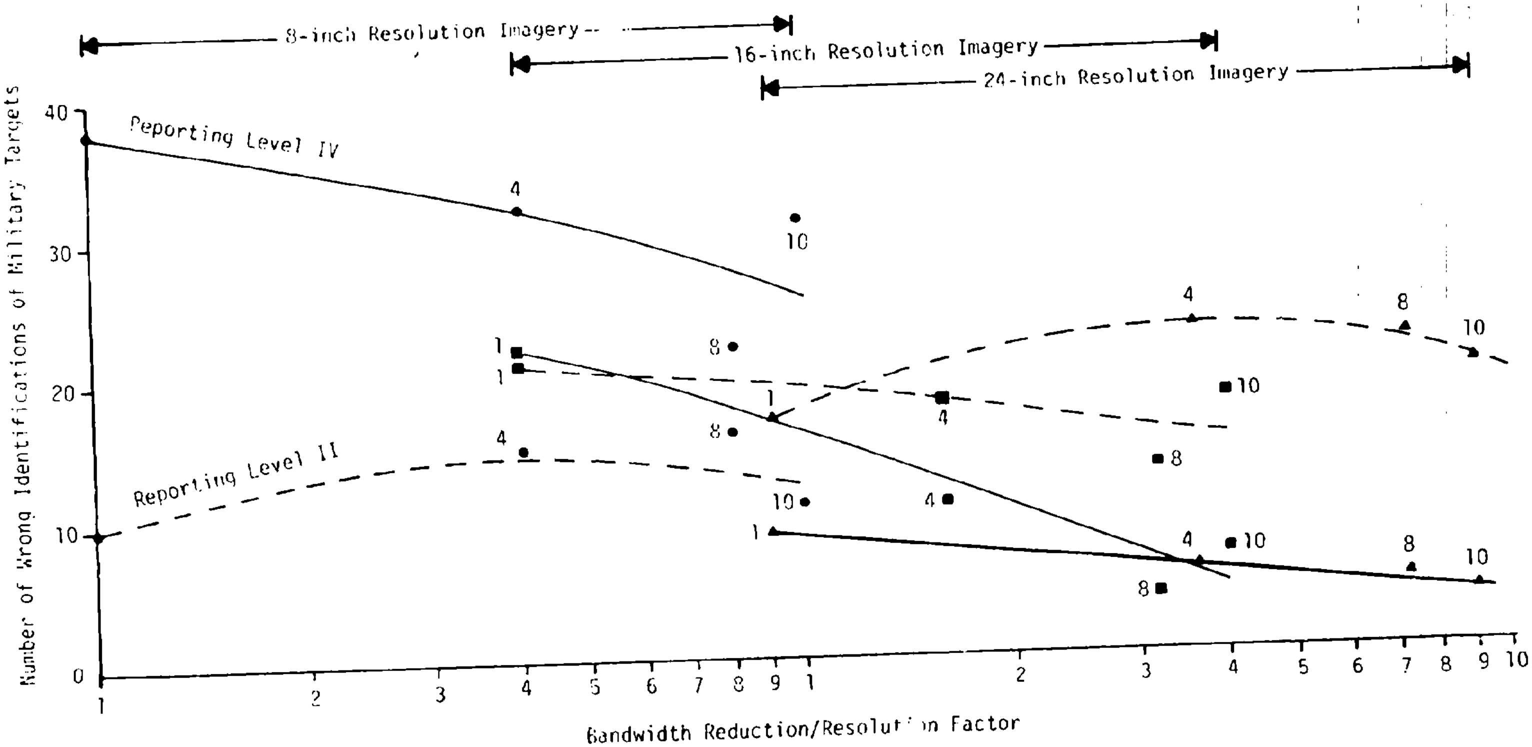
[3] In the training and practice period, the interpreters were instructed to report only those target identifications where they were "positive" of their identifications or where, at least, they felt them to be the "probable" identifications. (The "possible" level of certainty was to be eliminated.) These instructions appear in Appendix B. It is possible that this instruction may have reduced the number of wrong identifications.

Table 23

Number of Wrong Identifications, Bandwidth Compression Level Versus Ground Resolution x Reporting Level

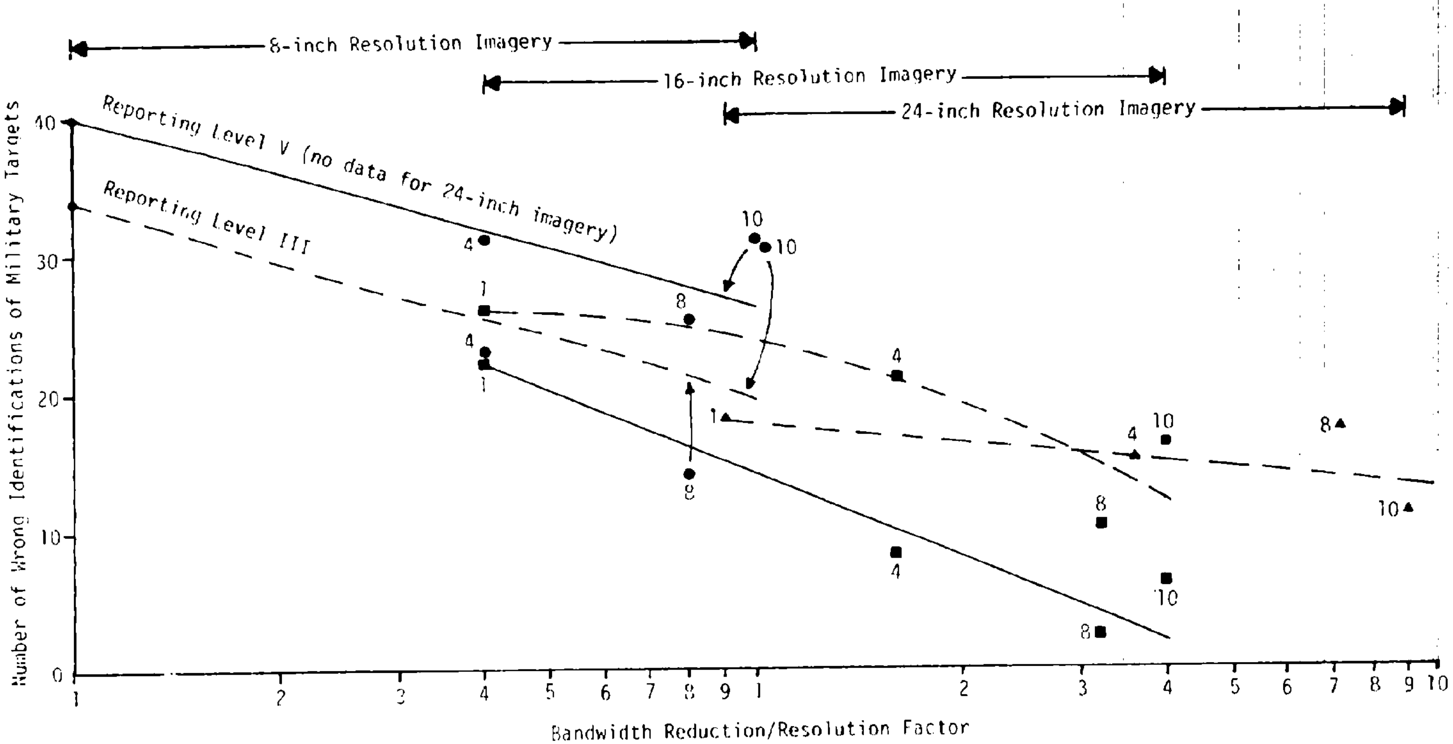
Bandwidth compression		Reporting level														
		I[a]			II			III			IV			V		
		GRD inches														
Ratio	Level	8	16	24	8	16	24	8	16	24	8	16	24	8	16[a]	24[a]
1:1	8+ bits/pel	--	--	--	10	21	17	34	26	18	38	22	9	40	--	--
4:1	2 bits/pel	--	--	--	15	18	23	23	21	15	32	11	6	31	--	--
8:1	1 bit/pel	--	--	--	16	13	22	14	10	17	22	4	5	25	--	--
10:1	.8 bit/pel	--	--	--	11	18	20	31	16	11	31	7	4	31	--	--
Total		--	--	--	52	70	82	102	73	61	123	44	24	127	--	--

[a] Insufficient data.



NOTE: See text for assumptions limiting comparisons across imagery

Figure 2. Effect of bandwidth reduction/resolution factor on number of wrong identifications for Reporting Levels II and IV.



NOTE: See text for assumptions limiting comparisons across imagery

Figure 3. Effect of bandwidth reduction/resolution factor on number of wrong identifications for Reporting Levels III and V.

3. Detection and identification of targets is generally reduced by low sun angle. For the detection of unobscured targets under low-contrast conditions, however, sun angle has no effect. (Analyzed only for the 24-inch GRD imagery.)

4. The reduction in target identification due to bandwidth compression occurs sooner at low sun angles than at higher sun angles (4:1 low sun and 8:1 for high sun). (Analyzed only for the 24-inch GRD imagery.)

5. A large decrease in performance occurs if the target is obscured (not in the open). Contrast, however, has no effect by itself within the range used. (Analyzed only for the 24-inch GRD imagery.)

6. Additional research is required to determine the effects of bandwidth compression under typical operational conditions, that is, those involving the search function and image interpreters better trained on compressed, digitized images.

7. The interaction effects of bandwidth compression, sun angle and target obscurity should be investigated more thoroughly under typical operational conditions, particularly for 8-inch and 16-inch GRD vertical imagery.

APPENDIX A

INTRODUCTION

Gentlemen, I am Harold Martinek of the Army Research Institute. I am the data collection and analysis part of a research team composed of image interpreters, engineers, human factors scientists, intelligence personnel, and so forth, from several organizations such as the Electronics Command, the U.S. Army Space Programs Office, and of course, the U.S. Army Research Institute.

Our purpose in this research is to make an initial determination of the effect of a bandwidth compression technique on the intelligence information generated by image interpreters. As you know, one problem with most imaging systems, particularly for mobile tactical targets, is getting the image from the platform to the interpreter in a timely manner. With some platforms it is a major problem. Electronic transmission is an answer but does have some problems associated with it--one of which we are looking into with this research; that is, the efficient use of bandwidth. In this electronic age we live in, bandwidth reduction is of critical concern to the Department of Defense. By mysterious mathematical theory, electronic black boxes, and computerized means, it is possible to reduce the bandwidth required to send an image. This bandwidth compression technique, while saving bandwidth, does affect the interpretability of the image. The questions are, how much and under what conditions?

An initial attempt at answering these questions is what we will be doing today and tomorrow morning. You will be asked to read out image chips varying in the amount of bandwidth compression used, in resolution, in the number and type of vehicles portrayed, in contrast, in the sun angle, and in the amount of vegetation around the target. Naturally, like all imagery, many other factors are present which affect interpretability, but they are not of concern in this research. Nor are we interested in your performance as an individual but only in how these variables affect interpreter performance.

ARE THERE ANY QUESTIONS AT THIS POINT ON THE PURPOSE OF OUR RESEARCH?

Today, we'll look at the target list, American equipment Mini-key, and the report form you will be using. Then we will review the imagery to give you practice with representative samples of all the resolutions, bandwidth compression levels, and target types you will be working with tomorrow during the actual data collection effort.

APPENDIX B

TRAINING INSTRUCTIONS

To help insure objectivity in this research, I want you to use only the words or numbers in this Vehicle Target List when reporting targets. We have found this procedure very helpful in past efforts to objectively evaluate the reports consistently. Note that there are five categories or columns of targets, going from the very general to the very specific. The fifth column refers to numbers on the U.S. Equipment Mini-key which you'll receive shortly. Each number is paired with a picture of a vehicle--the name, model number, and measurements are given. The group of numbers on one line in Column V, defines the word in Column IV on the same line. That is, on the first line number 3, 4, or 5, whatever they are on the Mini-key, define what an APC is for the purposes of this study. Similarly, on line 2, the numbers 1 and 2 or some other vehicle similar to these define the term "APC Other." Going to Column III, the term "APC Type" means the target is either an APC or an "APC Other." Again, going to Column II, Tracked Vehicle is defined by Column III, i.e., APC Type, SP Arty, Tank, or Recovery Vehicle. Column I is the most general target category, i.e., Military or Nothing. The latter could indicate that there was nothing on the picture or that there was an unidentified object that you are not sure enough about to report it as a military object.

In using this list you should always try to use the most specific term you can--if you can label an object as probably or positively an M48 Tank you would find the appropriate number on the Mini-key and write the number down. Perhaps you know it is a tank but cannot interpret it any finer--then report the word "TANK." Do not report "possible" objects--only probable or positive. That is, if the object is a "possible" M48, but a probable Medium Tank report Medium Tank. As you go from image to image and across different levels of resolution, try to keep the same standards of reporting--never reporting "possible" targets.

Use of several levels of target names like these will allow us to determine how much information can be extracted from an image of a particular type. Then we can pick the compression level which will allow the interpreter to provide the information the commander requires. In a sense, you will be setting the materiel specifications for future image systems.

ARE THERE ANY QUESTIONS?

The following steps were followed during this first day of the experiment. These items are not a part of the instructions given but were used as notes to keep the experimenter on course. They are listed here for record purposes only:

- **Review Target List**
- **Hand out Mini-key**
- **Review Mini-key (allow 15 minutes)**
- **Practice set for 8-inch Resolution**
- **Instruct participants to:**

  int :et 7 to 8 targets and check answers using scoring key,
  chec. wrong answers with Mini-key,
  interpret different set of images (labeled I to IV).

VEHICLE TARGET LIST

I	II	III	IV	V
MILITARY	Tracked Vehicle	APC Type	APC	3, 4, & 5
			APC Other	1, 2, Other
		SP Arty	SP Gun	6, 10, 12, 13, 14
			SP HOW	7, 8, 9, 11, 15
		Tank	Medium TK	16, 19
			Heavy TK	17, 18
		Recovery Vehicle	M578 Chassis	20, 21, 22
			Not M578	23, 24
	Wheeled Vehicles	Semi Truck With Trailer	Semi-Fuel	27, 28, 31, 32
			Semi-Cargo	25, 26, 29, 30, 33-36
		Heavy Truck	5 Ton +	37, 38, Other
			2½ Ton	44, 46, 48, Other
		Tank Truck	Water	40, Other
			Fuel	42, Other
		3/4 Ton Truck	3/4 Ton Cargo	49, Other
			3/4 Ton Other	51, 53
		1/4 Ton Truck	1/4 Ton Cargo	56, Other
			1/4 Ton Other	54, 55, Other
		Trailer	Caro Trl	47, 50, 57
			Special Trl	39, 41, 43, 45
	Trailers Artillery & Aircraft (TAA)	Arty Towed	Gun	92, 94, 95, 99
			HOW	93, 100, 101
			Missile	96, 97, 98
		Aircraft	Fixed Wing	Model #
			Rotary	Model #
	Engineer Equipment	Earth Moving	Tracked EM	85, 87
			Wheeled EM	76, 83, 84, 86
		Bridging	Tracked Bridge	73, 74, 75
			Wheeled Bridge	72, 82, 90
		Special Trucks	Engineer Trks	77, 80, 81, 88
			Truck Wrecker	58, Other
NOTHING	(Or Unknown)			

IMAGE TRANSMISSION STUDY

Photo Group ______________________

Photo Set ________ Start ______ End ______ Photo Set ________ Start ______ End ______

Photo #	Target ID	Remarks	Photo #	Target ID	Remarks

Practice 8-inch GRD Scoring Key

Photo #	II	III	IV	V	Remarks
			Scoring Level		
921	3 Wh Veh	Hvy Truck	5T+	37	M55
		Hvy Truck	2 1/2 T	44	M109
		Hvy Truck	2 1/2 T	48	M36
922	2 Wh Veh	3/4 T Truck	3/4 T other	51	Commo Shelter
		3/4 T Truck	3/4 T other	53	M43
923	Eng Equip	Special Truck	Trk Wrecker	58	M62
	Eng Equip	Earth Moving	Wh EM	83	Loader Schoop MTZ
924	Wh Veh	Tank Truck	Fuel	42	M49
	ATT	Trailer	Cargo Tlr.	47	M104
	Eng Equip	Earth Moving	Wheeled EM	76	Scraper Hvy w/Trac
925	Track Veh	SP Arty	SP Gun	10	M40
	Wh Veh	Semi-Trk	Semi-Cargo	35	M52
	ATT	Arty Towed	Gun	95	120mm
926	2 ATT	Arty Towed	Missile	96	M387E1 (LaCrosse)
		Arty Towed	HOW	100	M115
927	3 Track Veh	Tank	Heavy Tk	17	M60
		Tank	Med. Tk	19	M48
		Recovery Veh	M578 Chassis	21	M578
928	3 Track Veh	APC Type	APC	3	M75
		APC Type	APC	5	M59
		Recovery Veh	Not M578	24	M88
929	2 Track Veh	SP Arty	SP HOW	8	M37
		SP Arty	SP Gun	13	M107
930	Track Veh	SP Arty	SP Gun	14	M53

PRACTICE 16-INCH GRD SCORING KEY

Photo #	II	III	IV	V	Remarks
		Scoring Level			
911	2 Wh Veh	Hvy Truck 3/4 T Trk	2 1/2 T 3/4 T Cargo	46 49	M35 M37
912	2 Wh Veh	1/4 T Trk 1/4 T Trk	1/4 T 1/4 T Other	52 54	M38 M170
913	2 Eng Equip	2 Earth Moving	Wh EM Track EM	84 85	Grader MTZ Dozer
914	Wh Veh 2 ATT	Tank Trk Trailer Trailer	Water Special Trl Special Trl	40 41 43	M50 M107 Tk Fuel
915	3 ATT	Trailer Arty Towed Arty Towed	Cargo Trl HOW HOW	57 93 101	M100 M101 M114
916	Track Veh ATT	Tank Arty Towed	Med Tk Missile	16 97	M41 M386 (HJ)
917	3 Track Veh	Tank Recovery Veh Recovery Veh	Hvy Tk M578 Chassis M578 Chassis	18 20 22	M103 M578 (Chassis) M578
918	3 Track Veh	APC Type APC Type APC Type	APC Other APC Other APC	1 2 4	TRAC High Speed M106 M113
919	3 Track Veh	SP Arty SP Arty SP Arty	SP HOW SP HOW SP HOW	7 9 11	M52 M108 M110
920	Track Veh	SP Arty	SP HOW	15	M55

PRACTICE 24-INCH GRD SCORING KEY

Photo #	II	III	IV	V	Remarks
901	4 Wh Veh	Tank Trk	$2\frac{1}{2}$T Wtr	40	M50
		Tank Trk	$2\frac{1}{2}$T Fuel	42	M49
		Heavy Trk	$2\frac{1}{2}$T	44	M109
		Heavy Trk	$2\frac{1}{2}$T	46	M35
902	4 Track Veh	APC Type	APC Other	2	M106
		APC Type	APC	5	M59
		SP Arty	SP Gun	13	M107
		SP Arty	SP Gun	14	M53
903	4 Wh Veh	Semi-Trk with Trailer	Semi-Cargo	26	M15 (W Tank)
		Semi-Trk	Semi-Cargo	30	MDL Stv 620
		3/4T Trk	3/4T Other	51	Commo Shelter
		$\frac{1}{4}$T Trk	$\frac{1}{4}$T Cargo	56	M38
904	4 Track Veh	Tank	Med. Tk	16	M41
		Tank	Heavy Tk	18	M103
		Tank	Med. Tk	19	M48
		Recovery Veh	M578 Chassis	22	M578
905	Eng. Equip	Earth Moving	Wh EM	84	Grader
	Eng. Equip	Earth Moving	Track EM	85	Dozer
	ATT	Arty Towed	HOW	93	M101
	ATT	Arty Towed	HOW	101	M114
906	4 ATT	4 Arty Towed	Gun	95	120mm
			Missile	96	Lncher (LaCrosse)
			Missile	97	M386 (HJ)
			Gun	99	M59 (Carriage)
907	4 Eng Equip	Bridging	Tracked-Bridge	73	M48C
		Earth Moving	Wheeled EM	76	Scraper Hvy w/Trac
		Special Trk	Eng Trk	80	Dump M59
		Earth Moving	Wh EM	83	Loader Scoop MTZ
908	4 Eng Equip	Earth Moving	Wheeled EM	76	Scraper Hvy w/Trac
		Special Trk	Eng Trk	80	Dump M59
		Earth Moving	Tracked EM	87	Crane Shovel
		Special Trk	Eng Trk	88	M29C
909	4 ATT	4 Arty Towed	HOW	93	M101
			Missile	96	La Cros:
			Missile	97	M386 (HJ)
			HOW	101	M114
910	Track Veh	Recovery Veh	M578 Chassis	22	M578
	Track Veh	Recovery Veh	Not M578	24	M88
	Wh Veh	Semi-Trk w/Trl	Semi-Cargo	34	M127
	Wh Veh	3/4T Trk	3/4T Other	51	Van Commo Shelter

APPENDIX C

TEST PROCEDURES AND IMAGERY DESCRIPTION

You will be interpreting only 40 small image chips today at each of three resolutions for a total of 120 chips. Essentially, the imagery is the same as the practice imagery. Since each chip covers, on the average, only a 100 x 100 foot square on the ground, it can contain only a few targets--say from zero to about six or seven. I estimate the whole job should take 3 hours, but 4 hours have been allocated. As with the practice imagery, within each resolution the bandwidth compression level used will vary--thus some images within a group will be harder to interpret than others. Similarly, the contrast and sun angle vary within each group. This imagery is different from the practice imagery in that some targets are in the open while others are partially obscured. The scale varies from 1:1,000 to 1:3,000, and scale level will be furnished to you along with the photos. Two of the groups of images are vertical and one is oblique--additionally, the oblique is at the poorest ground resolution. The format is the same as the practice imagery.

Remember that some of the imagery will be quite poor, and perhaps even impossible to interpret. Just try to interpret it using the most detailed description you can from the target list but not reporting anything at the "possible" level.

ARE THERE ANY QUESTIONS?

NOTE: Allow approximately 50 minutes, followed by a break.

APPENDIX D

IMAGE MATRICES AND TARGET LISTS

Simulation Output Nomenclature Explanation

Each image mosaic is annotated as shown in Figure D-1 below. The top row is a mosaic identification number. The ten numbers in the next four rows correspond to image identification numbers assigned to the ten images in the mosaic. At the bottom of each mosaic is an experiment number 501-XXX. The mosaic number can be used to locate other pertinent information in Table D-1, such as resolution, scenario group, and bit rate. This information can be used in conjunction with the three experimental matrices given in Table D-2, Table D-3, and Table D-4 to determine sun angle, contrast, and whether the target is obscured or unobscured. Table D-5 to Table D-7 show the targets within each image and how they were scored at each reporting level.

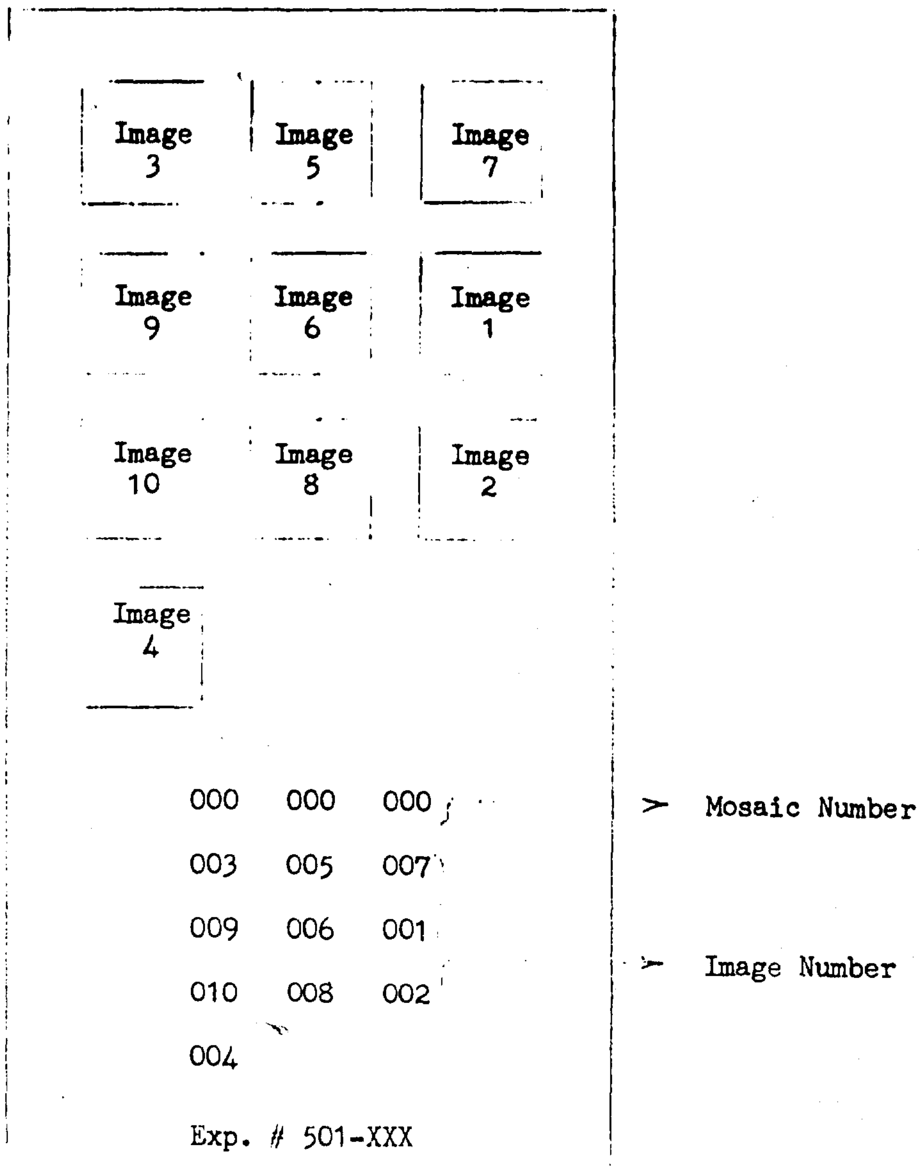


Figure D-1. Image mosaic annotation example.

Table D-1

Mosaic Number Versus Experimental Conditions

Mosaic number	Resolution	Scenario group	Bits/pel	Mosaic number	Resolution	Scenario group	Bits/pel
11	24"	IV	2	41	16"	II	2
12	16"	V	8	42	24"	II	0.8
13	8"	IV	8	43	16"	I	1
14	16"	IV	2	44	24"	IV	1
15	24"	III	1	45	24"	I	8
16	24"	V	0.8	46	24"	I	1
17	24"	III	2	47	16"	IV	1
18	16"	III	1	48	8"	III	2
19	16"	V	0.8	49	8"	II	8
20	24"	V	8	50	8"	I	0.8
21	16"	III	0.8	51	16"	II	1
22	8"	I	2	52	8"	V	2
23	8"	III	1	53	8"	II	2
24	8"	IV	2	54	8"	III	8
25	16"	V	1	55	24"	II	1
26	24"	I	0.8	56	24"	IV	8
27	16"	III	2	57	8"	V	0.8
28	16"	II	8	58	8"	V	8
29	16"	II	0.8	59	16"	III	8
30	8"	IV	0.8	60	24"	III	0.8
31	24"	V	2	61	24"	III	8
32	16"	IV	8	62	16"	I	0.8
33	24"	II	2	63	8"	I	8
34	8"	IV	1	64	8"	III	0.8
35	24"	V	1	65	16"	I	8
36	8"	II	0.8	66	16"	IV	0.8
37	24"	II	8	67	24"	IV	0.8
38	24"	I	2	68	8"	II	1
39	16"	V	2	69	8"	I	1
40	8"	V	1	70	16"	I	2

Table D-2

8" Sample Spacing Image Matrix
(Picture Numbers by Groups and Variables)

Scenario group	High sun angle				Low sun angle				No target	
	High contrast		Low contrast		High contrast		Low contrast			
	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured		
I	58	57	54	45	68	67	64	63	73	79
II	66	65	70	69	52	43	48	71	74	78
III	42	49	62	53	44	59	56	47	76	80
IV	50	41	46	61	60	51	72	55	75	77
V	Training									

Table D-3

16" Sample Spacing Image Matrix
(Picture Numbers by Groups and Variables)

Scenario group	High sun angle				Low sun angle				No target
	High contrast		Low contrast		High contrast		Low contrast		
	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured	
I	90	97	102	85	100	91	87	111	120 114
II	106	105	86	101	92	99	112	103	119 115
III	82	81	94	93	108	83	104	95	117 116
IV	98	89	110	109	84	107	96	88	118 113
V	Training								

Table D-4

24" Sample Spacing Image Matrix
(Picture Numbers by Groups and Variables)

Scenario group	High sun angle				Low sun angle				No target	
	High contrast		Low contrast		High contrast		Low contrast			
	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured	Obscured	Unobscured		
I	13	9	5	1	29	25	21	17	35	34
II	14	10	6	2	30	26	22	18	36	33
III	15	11	7	3	31	27	23	19	37	40
IV	16	12	8	4	32	28	24	20	38	39
V	Training									

Table D-5

Scoring Key for 8-inch GRD Imagery

Photo #	II[a]	III	Group 1 IV	V	Remarks
45	Tracked	Tank	Medium	19	M48
54	Two Tracked	2 SP Arty	2 Sp HOW	Two '15's	M55
57	Wheeled	1/4 T Trk	1/4 T Cargo	56	M355 or M38
58	Two Wheeled	1/4 T	1/4 T Cargo	56	
		3/4 T	3/4 T Cargo	49	M37
63	Two Wheeled	Cargo Trk	2-1/2 T	46 or 48	
		Tank Trk	Fuel	42	M49
64	OMIT				
67	Two Wheeled	1/4 T	1/4 T Cargo	56	M355 or M38
		Cargo Trk	2-1/2 T	46 or 48	M135 or M211
68	Two Trl, Arty and AC	Two Trailers	2 Special Trk	Two 41's	M107 or M149
73	--	--	--	--	--
79	--	--	--	--	--
			Group 2		
43	Five Tracked	Five APC Type	Five APC	Three 3's Two 5's	
	1 Wheeled	Cargo Trk	2-1/2 T	46 or 48	OK M135 or M211
48	Tracked	APC Type	APC	4	
52	1 Tracked	SP Arty	HOW	9	
	1 Wheeled	1/4 T Trk	1/4 T Cargo	56	M355 or M38
65	Trl, Arty, AC	Arty Towed	HOW	100	M115
66	Trl, Arty, AC	Arty Towed	HOW	101	M114
69	Two Trl, Arty, AC	Two Aircraft	Two Fixed	Two L19 Wing	
70	1 Trl, Arty,AC	1 Trailer	Cargo Trailer	57	M100
	1 Wheeled Veh	1 3/4 T	3/4 T Cargo	49	M37
71	2 Trl Arty,AC	Two Arty Towed	Two HOW	Two 93's	M101
	1 Wheeled	Cargo Trk	2-1/2 T	46 or 48	M135 or M211
74	--	--	--	--	--
78	--	--	--	--	--

[a]Category I score is number of vehicles in category II. In addition, score as correct words such as military, vehicles, unidentified vehicles, military objects, or any higher category words.

Table D-5 (continued)

Photo #	II	III	IV	V	Remarks
			Group 3		
42	Tracked	Tank	Medium Tank	19	M48
44	Three Tracked	Three Tanks	Three Medium Tk	Three 16	
47	Five Tracked	Five Tanks	Five Medium Tk	Five 19	
49	Tracked	SP Arty	SP HOW	9	108
53	Tracked	SP Arty	SP HOW	9	
56	Tracked	SP Arty	SP HOW	9	
	Wheeled	3/4 T	3/4 T Cargo	49	M37
	Trl, Arty, AC	Arty Towed	HOW	93,100,101	
59	Wheeled	Cargo Truck	2-1/2 T	46 or 48	Civ Veh is right for Cat I
	Score one extra correct for Category I only.				
62	Two Wheeled	1 Cargo Trk 1 3/4 T Trk	2-1/2 T 3/4 T Cargo	46, 48 49	M34,M35,M135,M211 M37
76	--	--	--	--	--
80	--	--	--	--	--
			Group 4		
41	Tracked	Tank	Medium Tk	19	M48
46	Tracked	Tank	Medium Tk	19	M48
50	Tracked	SP Arty	SP HOW	9	M108
51	Tracked	SP Arty	SP HOW	9	M108
	Wheeled	3/4 T Trk	3/4 T Cargo	49	M37
55	Tracked	SP Arty	SP Gun	13	M107
60	OMIT	OMIT	OMIT	OMIT	--
61	Two Wheeled	1 3/4 T Trk 1 Cargo Trk	3/4 T Cargo 2 1/2 T	49 46 or 48	
72	OMIT	OMIT	OMIT	OMIT	--
75	--	--	--	--	--
77	--	--	--	--	--

Table D-6

Scoring Key for 16-inch GRD Imagery

Photo #	II	III	IV	V	Remarks
			Group 1		
85	Tracked	APC Type	APC	4	M113
87	Four Tracked	2 APC Type	2 APC	Two 3	M75 Parts of
		2 Tank	2 Medium Tk	Two 19	M48 Tanks
90	Two Tracked	2 SP Arty	2 SP HOW	Two 16	M55
91	Tracked	SP Arty	SP HOW	9	M108
97	Wheeled	Cargo Trk	2-1/2 Ton	46 or 48	M34/M35
100	Three Wheeled	1-1/4 Ton Trk	1/4 Ton Cargo	56	38
		1-3/4 Ton Trk	3/4 Ton Other	53	Ambulance
		1-Cargo Trk	2-1/2 Ton	46 or 48	M135
102	Two Wheeled	1-1/4 Ton Trk	1/4 Ton Cargo	56	M38
		1-Cargo Trk	2-1/2 Ton	46 or 48	Same image as 67
111	Two Wheeled	1-3/4 Ton Trk	3/4 Ton Cargo	49	M37
		1-Cargo Trk	1-2-1/2 Ton Truck	48	M36
	Two Trl, Arty	2-Trailers	1 Special Trl	Not Listed	M139
	AC, TAA	1-Arty Towed	1 Cargo Trl	Not Listed	M101
			1 Missile	One 97	Honest John
120	--	--	--	--	--
114	--	--	--	--	--
			Group 2		
86	Four Tracked	Four APC Type	Four APC	Three 3	M75
				One 5	M59
92	Tracked	Sparty	SP HOW	9	M108
99	Two Tracked	Two Tanks	2 Med TK	Two 19	Out of picture
101	Three Wheeled	Two 1/4 Ton Trk	Two 1/4 Ton Cargo	Two 56's	M38
		One Cargo Trk	5 Ton	37 or 38	M56-M55-M41
103	Two Wheeled	Two 1/4 Ton Trk	Two 1/2 Ton Cargo	Two 56's	M38
	Score two extra rights for Category I only.				
105	Trailers Arty & A/C	Arty Towed	HOW	101	Same as image 66
106	One Tracked	SP Arty	SP HOW	9	M108
	Two Wheeled	1-1/4 Ton Trk	1/4 Ton Cargo	56	Trk's Same as image 102
		1-Cargo	2-1/2 Ton	46 or 48	
112	OMIT	OMIT	OMIT	OMIT	OMIT
115	--	--	--	--	--
119	--	--	--	--	--

Table D-6 (continued)

Photo #	II	III	IV	V	Remarks
			Group III		
81	Three Tracked	2 Tank	2 Medium	Two 19	M48
		1 Recovery	1 Not M578	One 24	M88
82	Tracked	APC Type	APC	4	M113
83	Two	Two	2 Medium	Two	M48
	Tracked	Tanks	Tanks	19	
93	Tracked	SP Arty	SP HOW	9	M108
94	Tracked	SP Arty	SP HOW	9	M108
95	1-Wheeled	1/4 Ton Truck	1/4 Ton Cargo	56	M38 or M355
	1-Tracked	SP Arty	SP HOE	9	Same as 52
104	OMIT	OMIT	OMIT	OMIT	OMIT
108	OMIT	OMIT	OMIT	OMIT	OMIT
117	--	--	--	--	--
116	--	--	--	--	--
			Group IV		
84	Two	2	2 Medium	Two	
	Tracked	Tanks	Tanks	19	
88	Two	Two	Two	Two	
	Tracked	APC Type	APC	3	M75
89	Tracked	SP Arty	SP HOW	9	
96	Tracked	SP Arty	SP HOW	9	
98	Wheeled	Cargo Trk	2-1/2 Ton Trk	46 or 48	
107	Trailer	Trailer	Cargo	47	
	Arty & A/C		Trailer		
109	Trailer	1	1 Fixed Wing	L19	Bird Dog
	Arty A/C	Aircraft			
110	2 Wheeled	3/4 Ton Trk	3/4 Ton Cargo	49	M37
		1/4 Ton Trk	1/4 Ton Cargo	56	M38
	1 Trl, Arty, AC	Trailer	Cargo Trl	57	M100
113	--	--	--	--	--
118	--	--	--	--	--

Table D-7

Scoring Key for 24-inch GRD Imagery

Photo #	II	III	IV	V	Remarks
		Group I			
1	Eng Equip	Special Truck	Eng Trk	80	M59
	Wh Veh	Heavy Truck	2-1/2 Ton	46	M35
5	Eng Equip	Earth Moving	Wh Em	84	
	Track Veh	SP Arty	SP Gun	13	M107
9	Track Veh	Tank	Medium Tank	19	M48
	TAA	Arty Towed	Missile	96	M387
13	Wh Veh	Semi-Truck	Semi-Fuel	32	M30
	TAA	Arty Towed	Missile	96	M387
17	TAA	Arty Towed	HOW	101	M114
	Track Veh	APC Type	APC	2	M106
21	Wh Veh	Semi-Truck with Trailer	Semi-Cargo	34	M127
	TAA	Arty Towed	Gun	99	
25	Eng Equip	Earth Moving	Wh Em	83	
	Wh Veh	1/4 Ton Truck	1/4 Ton Cargo	56	
29	Eng Equip	Earth Moving	Wh Em	76	
	Track Veh	Recovery Veh	M578 Chassis	22	
34	--	--	--	--	
35	--	--	--	--	

Table D-7 (continued)

Photo #	II	III	IV	V	Remarks
			Group II		
2	Wh Veh	Semi-Trk w/Trailer	Semi-Cargo	34	M127
	TAA	Arty Towed	Gun	95	
6	Eng Equip	Earth Moving	Tracked EM	85	
	Wh Veh	3/4 Ton Trk	3/4 Ton Other	51	
10	Eng Equip	Bridging	Tracked Brid.	73	M48C
	Track Veh	Recovery Veh	Not M578	24	M88
14	Track Veh	APC Type	APC	5	M59
	TAA	Arty Towed	HOW	93	M101
18	Track Veh	SP Arty	SP Gun	14	M53
	Eng Equip	Earth Moving	Tracked EM	87	
22	TAA	Arty Towed	Gun	99	M59
	Track Veh	Tank	Med Tk	16	M41
26	Wh Veh	Tank Truck	Water	40	M50
	TAA	Arty Towed	Missile	97	M386
30	Wh Veh	Hvy Truck	2-1/2 Ton	46	M35
	Eng Equip	Special Trk	Eng Trk	88	M29C
33	Omit 1 Military Object	--	--	--	
36	--	--	--	--	

Table D-7 (continued)

Photo #	II	III	IV	V	Remarks
		Group III			
3	Track Veh	Tank	Hvy Tank	18	M103
	TAA	Arty Towed	HOW	101	M114
7	TAA	Arty Towed	Missile	97	M386
	Wh Veh	Tank Trk	Fuel	42	M49
11	Eng Equip	Special Trk	Engineer Trk	88	M29
	Wh Veh	Heavy Trk	2-1/2 Ton	44	M109
15	Track Veh	SP Arty	SP Gun	14	M53
	Eng Equip	Earth Moving	Wheeled EM	84	
19	Wh Veh	3/4 Ton Trk	3/4 Ton Other	51	
	Eng Equip	Earth Moving	Track Veh	85	
23	Eng Equip	Earth Moving	Wh EM	84	
	Track Veh	Recovery Veh	M578 Chassis	22	M578
27	Wh Veh	APC Type	APC	5	M59
	TAA	Arty Towed	HOW	93	M101
31	TAA	Arty Towed	Gun	95	
	Wh Veh	Semi-Truck with Trailer	Semi-Cargo	30	
37	--	--	--	--	
40	Omit 1 Military Object	--	--	--	

Table D-7 (continued)

Photo #	II	III	IV	V	Remarks
			Group IV		
4	Eng Equip	Earth Moving	Wh EM	76	
	Track Veh	Recovery Veh	M578 Chassis	20	
8	Track Veh	APC Type	APC Other	2	M106
	TAA	Arty Towed	HOW	101	M114
12	Wh Veh	Semi-Trk w/Trailer	Semi-Cargo	34	
	Track Veh	SP Arty	SP Gun	14	M53
16	Eng Equip	Earth Moving	Wh Veh	83	
	Wh Veh	1/4 Ton Trk	1/4 Ton Cargo	56	
20	Wh Veh	Tank Truck	Water	40	M50
	TAA	Arty Towed	Missile	96	M387
24	Wh Veh	Semi-Truck	Semi-Cargo	34	M127
	Eng Equip	Spec Trk	Eng Trk	80	M59
28	Eng Equip	Earth Moving	Track EM	87	
	Track Veh	SP Arty	SP Gun	13	M107
32	Track Veh	Tank	Med Tk	19	M48
	TAA	Arty Towed	HOW	93	M101
38	--	--	--	--	
39	--	--	--	--	

APPENDIX E

CONTROL VARIABLE RESULTS

So as not to burden the results section of the report with a discussion of control variables, Appendix E has been prepared. Significant differences produced by these independent variables are described here for the sake of completeness.

Eight-Inch Ground Resolution Experiment

Right Identification Scores. Table E-1 shows the analysis of variance summary for the right identification scores by independent variable versus reporting level. Independent variables that significantly affected interpreter performance are indicated. Bandwidth compression level has been discussed in the body of the report and will not be given here.

Table E-1

Analysis of Variance Summary for Right Identifications, Independent Variables Versus Reporting Level (8-inch GRD)

Independent variable	Reporting level				
	I	II	III	IV	V[a]
Groups					-
Periods					-
Bandwidth compression level		**			-
Scenario	**	**	**	**	-
Residual					-

**Significant at the .01 level.

[a]Insufficient data.

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Table E-2 shows the number of right identifications per scenario by reporting level. That scenarios differ significantly among themselves is not unexpected. The eight chips scored in the ten image chips making up a mosaic comprise a scenario. The total number of targets, target size, target type, terrain characteristics, and so forth were controlled subjectively to make the four scenarios similar but they were not considered to be physically equal. Therefore, the number of correct responses differing significantly among scenarios at each of the four reporting levels (where there were sufficient responses to justify analysis) demonstrates the fact that the scenarios are not equivalent. In terms of interpreter performance in this study, it appears that if the scenarios were ordered in terms of difficulty they would range from S_2, the easiest, followed by S_4, then S_3, and finally S_1, the most difficult. For the number of right identifications there was no significant difference among groups for Reporting Levels I through IV. Reporting Level V performance was not tested due to lack of data.

Table E-2

Number of Right Identifications, Scenario Versus Reporting Level (8-inch GRD)

Scenario	Reporting level I	II	III	IV	V
S_1	86	62	28	9	3
S_2	109	86	50	25	12
S_3	90	76	37	19	5
S_4	102	84	46	25	10

Wrong Identification Scores. Table E-3 gives the analysis of variance summary data for independent variables versus the different levels of reporting. Three variables were significant--groups, bandwidth compression, and scenarios. Table E-4 gives the number of wrong identifications made by the four groups at each of four reporting levels. Reporting Level V was associated with a significant variation in the number of wrong responses produced by the groups. Groups 3 and 4 produced almost three times as many wrong identifications at this scoring level than did Groups 1 and 2. The groups of interpreters had been subjectively matched for ability by their supervisors and the finding that they are not equal in this one case indicated that the subjective equating of the groups was not perfect.

Table E-3

Analysis of Variance Summary for Wrong Identifications, Independent Variables Versus Reporting Level (8-inch GRD)

Independent variables	Reporting levels				
	I[a]	II	III	IV	V
Groups	-				*
Periods	-				
Compression levels	-		*		
Scenarios	-	**	**	*	**
Residual	-				

*Significant at the .05 level.
**Significant at the .01 level.

[a]Insufficient data.

Table E-4

Number of Wrong Identifications, Groups Versus Reporting Level (8-inch GRD)

Groups	Reporting level				
	I[a]	II	III	IV	V
G_1	-	20	19	18	14
G_2	-	9	23	21	17
G_3	-	15	41	46	51
G_4	-	8	19	38	45

[a]Insufficient data.

Table E-5 lists the number of wrong identifications by scenario and reporting level. As for the right identifications, the number of wrong identifications differs significantly among scenarios for each of the reporting levels. This is not unexpected since the scenarios were not equated in terms of the physical characteristics of the images involved. Except for Reporting Level II, S_2 again appears to be the easiest scenario.

Table E-5

Number of Wrong Identifications, Scenario Versus Reporting Level (8-inch GRD)

Scenario	Reporting level				
	I[a]	II	III	IV	V
S_1	-	4	16	32	35
S_2	-	29	13	14	12
S_3	-	9	52	44	46
S_4	-	10	21	33	34

[a]Insufficient data.

Sixteen-inch Ground Resolution Experiment

Right Identification Scores. Table E-6 gives the analysis of variance summary for the right identifications by independent variables versus reporting level. All of the independent variables were associated with significant differences at one or more of the reporting levels. In addition there was a significant residual found for the first reporting level indicating that there may be interactions among the independent variables.

Table E-7 shows the number of right identifications for the four groups of interpreters at the various reporting levels. At Reporting Level III, the performance of the groups differed significantly. Group 4 made many more correct identifications than did any of the other three groups. As previously mentioned for the 8-inch experiment, groups had been subjectively equated by their supervisors so that this significant difference is not startling.

Table E-6

Analysis of Variance Summary for Right Identifications, Independent Variables Versus Reporting Level (16-inch GRD)

Independent variables	Reporting level I	II	III	IV	V[a]
Groups			**		-
Periods			*		-
Bandwidth compression level	**	**	**	*	-
Scenario	**	**	*		-
Residual	*				

*Significant at the .05 level.
**Significant at the .01 level.

[a]Insufficient data.

Table E-7

Number of Right Identifications, Groups Versus Reporting Level (16-inch GRD)

Group	Reporting level I	II	III	IV	V[a]
G_1	78	46	10	5	-
G_2	80	50	12	4	-
G_3	63	37	12	6	-
G_4	66	63	30	17	-

[a]Insufficient data.

Table E-8 shows the number of right identifications for the four work periods in the study for each of the reporting levels. At Reporting Level III, performance differs significantly among the work periods. There were fewer correct responses in the first period and many more in the fourth period, indicating that there may have been a practice effect. That such an effect should be evident at only this one reporting level out of three experiments suggests that this may be a chance occurrence.

Table E-8

Number of Right Identifications, Periods Versus Reporting Level (16-inch GRD)

Period	Reporting level				
	I	II	III	IV	V[a]
P_1	79	45	9	8	-
P_2	70	41	14	5	-
P_3	79	52	14	6	-
P_4	79	58	27	13	-

[a]Insufficient data.

Table E-9 gives the number of correct identifications by scenario versus reporting level. Scenarios differ significantly for the first three reporting levels. As was argued for the 8-inch experiment, the scenarios were made similar but they could not be made identical for all image and target variables. That the scenarios differ significantly among themselves in terms of the number of correct responses made is evidence of their lack of equality.

Wrong Identification Scores. None of the control variables was associated with a significant difference in performance. The bandwidth compression variable was the only independent variable for which there was significance. That variable is discussed in the body of the report.

Twenty-Four-Inch Ground Resolution Experiment

Right Identification Scores. None of the control variables was associated with a significant difference in performance.

Table E-9

Number of Right Identifications, Scenario Versus Reporting Level (16-inch GRD)

Scenario	Reporting level I	II	III	IV	V[a]
S_1	65	42	14	9	-
S_2	86	57	27	11	-
S_3	45	30	8	4	-
S_4	111	67	15	8	-

[a]Insufficient data.

Wrong Identification Scores. None of the independent variables was associated with a significant difference in performance at any reporting level.

APPENDIX F

SIGNIFICANCE TESTS USING THE NEWMAN-KEULS METHOD

For each situation in which the bandwidth compression variable produces a significant change in interpreter performance, mean performance at each of the four levels of the bandwidth compression variable was tested using the Newman-Keuls Method (5% level of confidence) to determine which of these levels significantly affected performance.

Eight-Inch GRD Experiment, Right Identifications

At Reporting Level II, bandwidth compression was associated with significant variation in interpreter performance. Mean performance at all four reporting levels was significantly better at the 8+ bits/pel level than performance for any other three bandwidth compression levels. Any amount of bandwidth compression significantly degrades performance.

At the .8 bit/pel level, performance was significantly better than that at 1 bit/pel. This result was contrary to expectation.

Eight-Inch Experiment, Wrong Identification

At Reporting Level III, bandwidth compression differences significantly affected interpreter performance. The 8+ bits/pel and the .8 bits/pel levels were both found to have significantly more wrong responses than either the 2 bits/pel or 1 bit/pel level.

Sixteen-Inch Experiment, Right Identification

Bandwidth compression significantly affected performance for Reporting Level I through IV. Differences for each reporting level are described separately.

- Reporting Level I: At the 8+ bits/pel and the 2 bits/pel levels, mean performance was significantly better than at 1 bit/pel and .8 bit/pel.

- Reporting Level II: At the 8+ bits/pel and the 2 bits/pel levels mean performance was significantly better than that at 1 bit/pel and .8 bit/pel.

- Reporting Level III: At 8+ bits/pel, performance was significantly better than that at the other three bandwidth compression levels. Additionally, mean performance at the 2 bits/pel level was significantly better than that at 1 bit/pel and .8 bit/pel.

- Reporting Level IV: At the 8+ bits/pel level, mean performance was significantly better than that at the 1 bit/pel level only.

For the number of right identifications, performance did not drop significantly with bandwidth compression before an 8:1 compression ratio was reached. This performance followed expectations as lowered performance was associated with greater compression. At Reporting Level IV, one inversion occurred, with performance at 1 bit/pel slightly below that at .8 bit/pel.

Sixteen-Inch Experiment, Wrong Identification

Bandwidth compression level produced significant differences in interpreter performance for Reporting Levels IV and V.

- Reporting Level IV: At the 8+ bits/pel level, interpreters made more wrong identifications than at the 1 bit/pel and .8 bit/pel levels.

- Reporting Level V: At the 8+ bits/pel level, interpreters made significantly more wrong identifications than at any of the other three bandwidth compression levels.

Twenty-Four-Inch Experiment, Right Identifications

Bandwidth compression level was associated with significant differences for Reporting Levels II, III, and IV.

- Reporting Level II: The 8+ bits/pel and 2 bits/pel compression levels were associated with significantly better performance than were the 1 bit/pel and .8 bit/pel levels.

- Reporting Level III: The 8+ bits/pel and 2 bits/pel levels were associated with performance means that differ significantly from those obtained at 1 bit/pel and .8 bit/pel.

- Reporting Level IV: At 8+ bits/pel, mean performance was significantly better than for the other three levels.

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